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SUSTAIN™
Sustainment Strategy for Avionics Information Needs

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Introduction

The primary directive for a military systems sustainer is to provide support to the warfighter by insuring that his weapons system is operational and available. That requirement is the bottom line, but there are myriad ways of accomplishing it at vastly different costs. Combined with the fact that military weapons systems are being called upon to remain in service far past their design lifetime, increased importance is placed on the system sustainer to make correct decisions, especially considering the shrinking military budgets. There is a wealth of data available for the sustainer to use in making decisions, including historical reliability and cost, spares availability, future planned use and, perhaps most importantly in the near term, component obsolescence. An efficient, mechanized method of analyzing all the data available to the sustainer is needed to help him, or her, make correct decisions at the correct time.

Component obsolescence is not a problem for military avionics systems ...until that component threatens mission readiness. First generation component obsolescence tools evaluated individual component obsolescence in a vacuum. Second generation tools monitor component obsolescence at a board, box, or even system level and provide an estimate of "system health" and may even allow sharing of information across systems. Neither of these approaches answers the basic question of when an obsolete component will affect mission readiness. Without that information, it is impossible for the sustainer to make the best decisions. For example, there may be a severe obsolescence problem on a particular board of an aircraft radar system. But if that board exhibits good reliability and there are adequate spare assemblies available, then addressing this particular obsolescence issue may be postponed, perhaps indefinitely.

What is required is a true sustainment tool that allows implementation of a "just-in-time" sustainment approach, by consolidating all the required information into a single automated tool which displays data in a concise and informative manner. The tool should identify and prioritize the sustainment actions required and also tell the sustainer when each action must occur in order to avoid any compromise to mission readiness. The sustainment actions must be identified far enough in advance so that they can be planned for, budgeted for, and implemented before any aircraft are grounded. The following paragraphs describe the characteristics required of such a tool and the program instituted by the Warner Robins Air Logistics Center to develop such a program.

Required Characteristics of a Sustainment Software Tool

The minimum requirements for a sustainment software tool are that it should:

- Be **relevant** to the needs of the user
- Perform **accurate** data analysis
- **Completely** consider all relevant information
- Perform **timely** analysis of up-to-date data
- Be **user friendly** in its data entry and presentation

Additional implementation concerns include modular software organization and flexible data analysis capability. Each of these areas is discussed in the following sub-sections.

Relevance

The sustainer of a military weapon system provides a service to the user of that system and, often, funding for that service is provided by the user. It is incumbent upon the sustainer to base decisions on the needs of the user. Therefore, for a military weapon system, the primary metric for any sustainment decision must be mission readiness. A secondary metric is the cost to maintain a given level of mission readiness. Decision metrics based solely on cost are very likely at some time to overlook a significant mission readiness driver because it does not provide an adequate return on investment.

Accuracy

The sustainer must believe the results presented by the analysis tool and, in turn, his superiors and the users must also be convinced that the tool is providing accurate data. In order to meet this requirement, the results must be traceable back to the input data and most importantly, the input data must be correct. "Officially approved" databases should be used wherever possible as the source for defendable, accurate data. If "official" data bases do not exist, then historically accurate and widely used data sources should be selected.

Completeness

Consideration of all aspects of system sustainment is required for accurate results and is the most difficult part of developing a sustainment tool. A complete sustainment tool must have the following attributes:

1. Sustainment issues must be addressed from the component level up to no lower than the system level (i.e., radar system, EW system, etc.) and preferably to the platform level for all equipment for which the sustainer is responsible.

2. All variants of each system and their interchangeability must be included.

3. Spares at all levels (i.e., component, board, box, etc.) must be considered including the assembly indenturing.

4. Component obsolescence must be determined.

5. Repair history to the component level must be available.

6. Force structure effects should be included.

As mentioned above, these data should be obtained from "official" databases to insure data accuracy.

Timeliness

There are two aspects to timeliness in this setting. First, the data must be up-to-date so that the analysis results are current. Second, the analysis algorithms must be able to accurately predict up to five years in the future and farther than that with decreased fidelity. And further, the analysis must be performed in an efficient manner so that data latency is minimized.

User Friendliness

If the sustainer will not use the software, then it is of no use. The two main requirements in this regard are first, since there is a very large amount of data to be analyzed, the data must be available electronically and the data input and analysis must be largely automatic. And second, the processed data must be presented in an unambiguous and easily understood manner.

Implementation Considerations

The benefits of modular software have been proven. If the sustainment tool is destined for more than one application, then some customization for each user should be anticipated. With modular software, additional capabilities can be added to a baseline capability at minimal expense so as to provide only those capabilities required by the user. The tool should also be flexible to allow "what-if" scenarios to be postulated and explored by the sustainer.

SUSTAIN™

The SUSTAIN™ (Sustainment Strategy for Avionics Information Needs) program is a comprehensive software sustainment tool with the above characteristics. Its development is being sponsored by the Warner Robins Air Logistics Center F-15 Avionics Hardware Section (WR-ALC/LFEFA). In 1989 this group at Warner Robins began an aggressive program to combat integrated circuit (IC) obsolescence in the F-15 avionics. That program has been in the forefront of obsolescence resolution activities in the USA and has a proven history of success. As their program evolved and matured, LFEFA recognized the need for a comprehensive sustainment tool to add to the AVCOM component obsolescence evaluation tool. The Georgia Tech Research Institute has been working with WR-ALC/LFEFA since 1989 on various sustainment activities for the F-15 avionics and is currently developing SUSTAIN™. This tool is being developed to support those avionics systems unique to the F-15 for which WR-ALC/LFEFA has sustainment responsibility. Electronic warfare systems, jet engines, and common items, such as radios, are not currently included in SUSTAIN™. Specialized contractor repair items-are also not included because, in many cases, LFEFA does not have the insight into the components of those devices to effectively support them.

The SUSTAIN™ concept is quite straight forward, but the implementation is necessarily somewhat complicated. Real historical data are used wherever possible to calculate the required parameters as noted below. The only estimated information is the predicted component obsolescence. It is assumed that the component usage rates measured today are predictive of the future usage rates and are used to predict required sustainment actions.

The basic functional modules that comprise SUSTAIN™ include the mission readiness function, the sustainment action function, the sustainment cost function, and the technology insertion function. Additional potential capabilities include a sensitivity analysis function and a reliability

analysis function. The following paragraphs describe the above functions including the databases utilized and examples of output plots.

Mission Readiness Function

This function is the heart of this sustainment concept. Two metrics for determining mission readiness are computed by SUSTAIN™; the mission incapable (MICAP) vulnerability versus time and the mission degradation versus time. The main difference between these metrics is that MICAP vulnerability is a system view while mission degradation is a lower level look at the assemblies that make up the system. In order to compute these metrics, detailed knowledge of the system, its components, assembly interchangeability, spares at all levels, force structure, component repair information, Defense Logistics Agency (DLA) inventory and usage rates, and component obsolescence are required. Table 1 lists the data required and the source of the data. All data sources are updated on a quarterly basis.

Table 1. Mission Readiness Data

Required information	Data Source
System structure, indentured parts list and interchangeability	Illustrated Parts Breakdown T.O. Contained in AVCOM (MTI Inc.)
Component obsolescence	AVCOM (MTI Inc.)
System spares and requirements	Express (USAF)
Component inventory and usage rates	DLA (DoD)
Depot repair data	Avionics Repair Knowledge Base (Warner Robins ALC) Work Documents and MPS System (Ogden ALC)
Force Structure	TBD

System Structure

Information on system assemblies including the indentured parts list and assembly interchangeability is taken from the official USAF Illustrated Parts Breakdown Technical Order. This information, for the F-15, is contained electronically in the AVCOM component obsolescence tool. This proven tool was developed by Manufacturing Technology Inc. (MTI) and has been in use by the F-15 sustainers for several years.

Component Obsolescence

AVCOM also contains the current status of component availability and predictions as to future availability of approved components. Only those components currently listed as obsolete are included in the MICAP vulnerability evaluations.

System Spares and Required Inventory

Express is an official USAF database that summarizes data from several other databases. It is used by SUSTAIN™ to supply the number of spare assemblies at all levels (LRU, SRU, sub-assembly, etc.). The assemblies are divided into several categories, including those that are either

serviceable, repairable, in-transit, non-repairable, etc. The repairable category may then require further subdivision if an assembly is awaiting parts (AWP) that are obsolete and unobtainable. That determination is made from data obtained from the facility at which that assembly is repaired. Also itemized in Express are two required spares quantities for each assembly in the system: the peace-time operating spares (POS) level and the war readiness materiel (WRM) level. These spares quantities are official USAF determined values. The POS level is the lower of the two spares levels and is a minimum spares quantity required to support world-wide peacetime operations. The WRM level is no less than the POS level and contains additional spares required in the case of a conflict situation.

Component Inventory and Usage Rates

"The Defense Logistics Agency is a logistics combat support agency whose primary role is to provide supplies and services to America's military forces worldwide." (http://www.dla.mil/) For the F-15 application, DLA has been contracted to provide information on all components (primarily integrated circuits) of interest to this aircraft. For a set of national stock numbers (NSNs), DLA provides the quantity on hand and the historical demand rate for that NSN over the last eight quarters in electronic format. These data are updated quarterly. Note that the demand rate is for all organizations that order through DLA and includes more than F-15 usage. This information is used to forecast for how long DLA will be able to furnish components for the systems under study.

Depot Repair Data

The F-15 unique avionics are primarily maintained at two ALCs; Warner Robins and Ogden. To our knowledge, a USAF-wide depot repair database does not exist, so local databases are used to capture repair history. For the SUSTAIN™ application, repair history of all systems down to the component level, including the reference designation, is desired. This allows the program to determine the F-15 unique usage rate for each component in the systems under consideration. Additionally, information on AWP assemblies may be analyzed to determine if an assembly is waiting for an unobtainable component. If that is the case, then that assembly should be eliminated from the spares inventory, but if the assembly is waiting for an available component, then it will be counted in the spares inventory.

Force Structure

SUSTAIN™ assumes that the current failure rates per flying hour will be constant into the future. As the number of aircraft, or the number of flying hours per aircraft change, then the total number of failures for a component on a board will change. The force structure numbers are based upon USAF Air Combat Command estimates.

Mission Readiness Computation

SUSTAIN™ determines the impact on mission readiness of unobtainable components in the following manner. The date at which components are predicted to become obsolete is predicted by AVCOM. On this date it is assumed that the component can no longer be acquired from a commercial vendor. The DLA inventory and usage rate of that component is then used to determine when the DLA inventory will be exhausted. At that point in time, any future failures of that component in the system under consideration are considered to be non-repairable. The impact of that unavailable component on every assembly in the system is then determined based on the historical depot repair history and anticipated force structure. Then, as future failures are expected to occur, the spare assemblies are drawn down to repair the systems. All

interchangeable assemblies are included in the analysis. When all the interchangeable assembly spares are exhausted, then next higher level assemblies are cannibalized for the required assembly. Additional spares (of different assemblies) resulting from the cannibalization are added to the available spares as appropriate. This process is continued all the way up to the system or aircraft level for all systems under consideration. When the number of spare assemblies drops below the WRM level then a mission degradation situation is predicted in which some aircraft will be grounded for a period of time (a temporary MICAP) due to an insufficient spares supply. When the number of spare assemblies drops below zero (i.e., the number of operational assemblies is less than the number of aircraft), then a permanent MICAP will occur. Figures 1 through 3 present typical plots of the mission readiness evaluation for a notional avionics system. A single line-replaceable unit, L-12, is primarily responsible for System 1 depletion, as depicted by Figure 1. Shop-replaceable unit slot S-122A,-122B is responsible for L-12 depletion, as seen in Figure 2. The plots shown in Figure 3 reveal that five microcircuits contribute to slot S-122A,-122B depletion. Three microcircuits, P-36, P-37, and P-39 are identified as depletion drivers. MICAP analysis indicates that extended MICAPs due to System 1 can be deferred for several years if sustainment action is taken for the three aforementioned parts.

Sustainment Action Function

The sustainment action function is intended to assist the sustainer to identify the part-level actions required to maintain the system. Those components identified by the mission readiness function as causing MICAPs or mission degradation within the analysis period are targeted for action. In addition, components that are predicted to become obsolete are included in the analysis. Thus, depending on the time frame under consideration, most, if not all, components may be targeted for sustainment actions. This module accounts for uses of redesigned components in each application in the system under consideration and across systems on the platform. Thus, redesign/replacement of an obsolete IC on one board will solve that same IC's obsolescence problem in all applications. An "Action Code" is assigned to each component indicating the urgency with which the component obsolescence must be addressed.

Historical sustainment action information and a part solution/cost matrix supplement the above data. Based on the type of component that is unobtainable (digital, analog, ASIC, hybrid, etc.) a specific type of sustainment action is recommended which could vary from a relatively minor form, fit, function and interface (F^3I) component replacement to a major redesign of a hybrid. Thirty different sustainment actions are currently supported by SUSTAIN™, plus flags for insufficient component data. Information on the component type is contained in AVCOM and

Figure 1. System- and LRU-level Depletion Curves

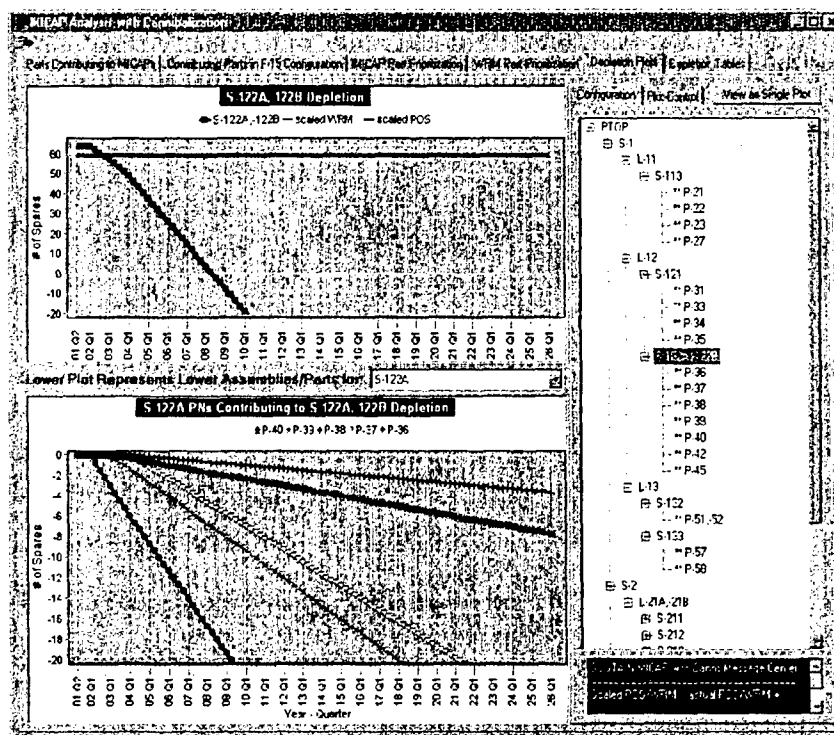Figure 2. LRU- and SRU-level Depletion Curves

Figure 3. SRU- and Microcircuit-level Depletion Curves

the recommended action is obtained from historical data on sustainment actions for similar components. The part solution/cost matrix contains data on the costs and schedule for performing each type of sustainment action and is also based on historical data.

Additional electronic data that would enhance the sustainment action function includes refined information on aftermarket suppliers and their inventory of components or IC die and information on life-time buy opportunities. Some of this data is currently used by SUSTAIN™, but automating the updating of this data could be quite important in determining the best component sustainment action.

Sustainment Cost Function

The sustainment cost function in SUSTAIN™ is strictly defined as the sum of two parts: the costs associated with assembly returns to the depot for repair (referred to as "not repairable this station" or NRTS assemblies) and the predicted costs of F^3I component obsolescence resolution. No other costs are included in this calculation. This cost metric therefore captures the costs associated with the reliability of each NRTSed assembly, all depot costs (manpower, test equipment, overhead, etc.), and obsolescence effects. Specific costs not captured by this approach include manpower at the O and I (organizational or flight-line and intermediate) level shops, costs of test equipment at the I level shop, cost of can-not-duplicate (CND) failures at I level, and repairs accomplished at I level.

The NRTS costs are determined by the number of NRTS actions for each assembly returned to the depot for repair and the exchange cost for that assembly which is obtained from standard government databases. Obsolescence resolution costs are obtained from the Sustainment Action function.

Technology Insertion Function

The technology insertion function assists the sustainer to optimize sustainment actions. It automates the task of comparing sustainment solutions at several levels, i.e., component, board, assembly, box or system. This function examines the component obsolescence of each assembly in the indentured assembly list and correlates those projections to determine when it might be more cost effective to replace a higher level assembly rather than a component. For example, if it is predicted that several components on one board will become unobtainable in a short span of time and replacement of those components will cost $2 million, but redesign of that board would cost $1 million, then it might be more cost effective to redesign at the board level. Other considerations that SUSTAIN™ takes into account include the impact on other assemblies of component redesign, failure rates, the risks of each potential solution and the estimated reliability of each solution. Assumptions that are made by SUSTAIN™ include that the redesigned assembly is F^3I and that the impact on I level and depot test equipment is minimal.

Additional Capabilities

Sensitivity Analysis Function

The sensitivity analysis function allows the user to determine the sensitivity to certain actions by postulating "what-if" situations which are then analyzed in a normal fashion by the SUSTAIN™ software. For example, if an obsolescence resolution action were postponed, or if the force structure were changed, then the program would provide the capability to quickly evaluate the impact of that action in terms of mission readiness. This feature could also be very useful to maximize mission readiness while operating within budget constraints.

Reliability Analysis Function

This capability elevates the functionality of SUSTAIN™ to become a complete one-stop sustainment tool. This function would identify those assemblies that are maintenance drivers from either a failure point of view or from a maintenance man-hours perspective. To accomplish this capability, maintenance data from the intermediate repair shop and from the depot (and potentially organizational level) would be gathered to determine the number of aircraft removals, the I-level CND rate, the NRTS rate of each assembly and by correlating serial numbers or work order numbers, the depot repair action. Reliability statistics can then be easily computed and reliability drivers determined. These data may then be used to get an estimate of the true cost of ownership of each assembly studied. By then correlating the reliability, cost of ownership and mission readiness information, the best sustainment decisions may be made.

Conclusions

SUSTAIN™ is being developed to be relevant to the needs of the user, and to provide accurate and complete data analysis in a timely and user friendly manner. The unique feature of the concept is that it takes advantage of the large amount of data available to the sustainer and processes that data in a manner that is most useful to him or her.

Relevance is insured by using mission readiness as the primary metric for evaluating potential sustainment actions. Additional information comes from the automatic calculation of the sustainment cost for each assembly under consideration.

Accuracy of the output is guaranteed if the analysis algorithms are correct and the input data are correct. By using only government approved or acknowledged databases, then the data accuracy is as good as can be obtained.

Completeness of the analysis is obtained through examination of the complete indentured parts list for each system included in SUSTAIN™ and through inclusion of all data relevant to the sustainment process.

Timely data is insured through quarterly data updates from each data source. Projections of sustainment actions from 5 years to 25 years are automatically generated.

User friendly, unambiguous output data format is a main goal of SUSTAIN™. Data updates are also performed automatically on data provided electronically.

The initial capability of the program was demonstrated in the spring of 2001 and complete capability is expected in mid-2002.